Climate Change, Food Sovereignty, and Ancestral Farming Technologies in the Andes

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ABSTRACT

Indigenous people are among the populations most vulnerable to climate change. However, indigenous societies' potential contributions to addressing climate change and related issues of food security are vast but poorly recognized. The objective of this report is to inform the nutrition and public health communities about the potential contributions of ancient Andean technologies to address these contemporary challenges. Our research examines these ancient farming technologies within the frame of climate change and dietary potential. Specifically, we focus on 4 technologies derived from 3 case studies from Ecuador. These technologies were analyzed using evidence mainly of adaptation to climate change in indigenous-based agriculture. Our examination of these technologies suggests they could be effective mechanisms for adapting to climate change and protecting food sovereignty. Thus, although highly vulnerable to climate change, indigenous peoples in the Andes should also be seen as "agents of change." *Curr Dev Nutr* 2021;5:nzaa073.

Keywords: food sovereignty, climate change, micronutrients, cultural diet, adaptation, mitigation, ancestral farming technologies, Andes

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Introduction

For over a decade, the Intergovernmental Panel on Climate Change (IPCC) has highlighted the consequences of climate change in rainfall and temperature, along with increasingly severe weather events. These consequences jeopardize the survival of humans because climate change directly affects agricultural production, food security, and nutrition (1). This scenario, as conveyed by scientists worldwide, represents a "climate emergency" (2).

Paralleling Western science, changes in weather and climate patterns have been observed and understood by indigenous societies around the globe, in part because of their often extreme reliance on nature (3). Indigenous people are also considered among the most vulnerable populations (4), partly because of their limited access to modern technology. Nevertheless, as the IPCC has recognized, indigenous knowledge is pivotal to adaptation to climate change (5).

In this context, our contribution focuses on ancient farming technologies still being used by indigenous Andean populations. These technologies, although increasing exponentially the quantity of crops produced, also guard against phenomena associated with climate change, such as soil erosion, drought, hailstorm, frost, and flooding. Furthermore, they are capable of supporting a variety of highly nutritious crops, thus improving access to healthy, culturally adequate, and nutritious foods within indigenous communities.

Methods

Population

The Andes is both a geographic and cultural area, with Andean populations sharing many cultural traits even among geographically distant places of Peru, Ecuador, and Bolivia. According to the most recent national censuses in Peru (2017), Ecuador (2010), and Bolivia (2012), indigenous people represent, respectively, 26%, 7%, and 40.6% of each country's populations (6–8). Indigenous people in these 3 Andean countries are mainly concentrated in the rural sector. Indigenous settlements are located across the geographic spectrum, from the high Andes to the Amazonian lowlands, and in coastal regions of Peru and Ecuador. Currently, these populations embody the paradox of being key actors in the region's food system (9) while disproportionately experiencing food insecurity and chronic undernutrition (2).

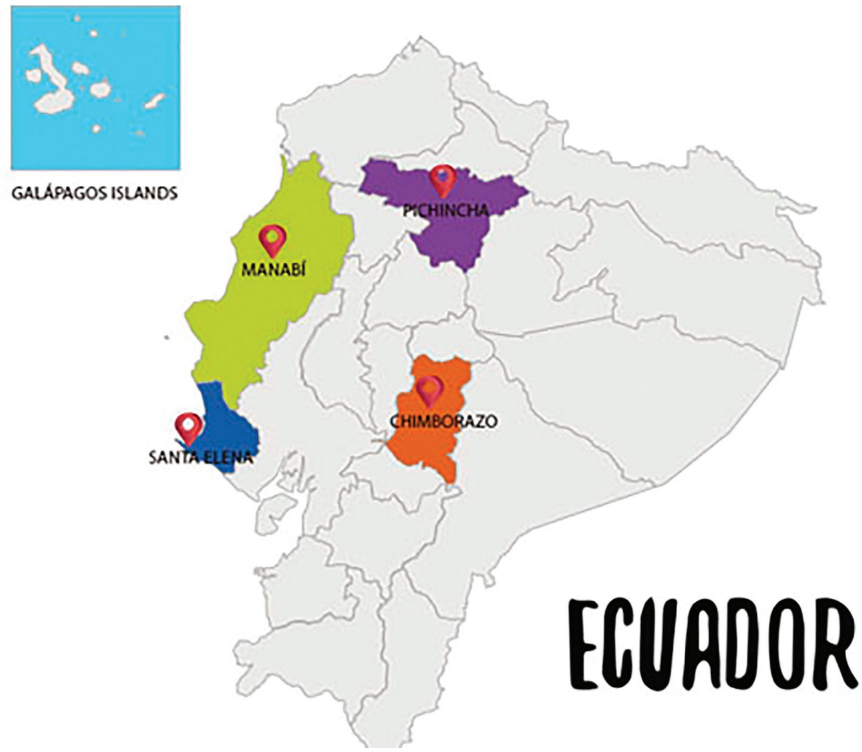

FIGURE 1 Eparta Sevilla. Studied sities in Ecuador. 2020

FIGURE 2 Amaya Carrasco. Terraces in Quito. 2020

Conceptualizing climate change in the Andes

Climate change in mountainous Andean areas is having a profound impact on food security by affecting water sources and crop production. Climate change is rapidly melting glaciers that provide water for human consumption and for agrarian activities in the Andean lowlands (10). Intense rains increase the risk of landslides, as well as flooding, posing a serious risk to harvests (3, 11). Rains alternating with extreme droughts also affect growing cycles (11, 12). Finally, crops in mountainous areas of the Andes are especially susceptible to frost (12, 13) and hailstorms (12). In the northern Ecuadorian Andes, ashfalls from recurrent volcanic events also represent a major hazard to agriculture. These combined effects of climate change and other natural disasters compromise food security, particularly among indigenous populations often highly dependent on subsistence agriculture.

Procedures

We conducted a retrospective, observational, and integrative study combining: *1*) secondary information sources that met the 2-fold criteria of current usage and suitability of ancestral technologies to present times; *2*) 3 relevant, independent, primary research experiences in Ecuador, representing firsthand experience with 4 ancient farming technologies currently active; and *3*) plant species grown using ancient farming technologies, with reference to the micronutrient content of these species.

Secondary information sources included published articles in peer-reviewed journals, white literature (e.g., regulations and reports by government and international organizations), and gray literature (non-governmental organizations' reports and newspapers). Primary research was represented by 3 studies in Ecuador over the last 2 decades (**Figure 1**). The coauthors of this report directly participated in these 3 studies, which represent direct access to the methods, data, and documentation of the agroecological spaces and communities that rely on ancestral technologies in active use today. Although the studies had different objectives, methods, and populations, all included structured and semistructured observations allowing a detailed description of ethnographic and agroecological landscapes (14, 15). The first study, in the Santa Elena Peninsula and the Guayas Basin (late 1990s and early 2000s), was part of a community-based applied archaeology and heritage empowerment project. The second study, in an indigenous rural community of the central highlands (April to December 2018), included a mixed-methods design site analysis that accounted for sunlight and water patterns, architecture (in the agroecological sense), slope of the terrain, and agrobiodiversity. The third study (June to July 2019) was a qualitative exploration of urban agriculture in Quito focused on agriculture, food sovereignty, and climate change, including site visits to indigenous populations that have settled on hillsides in the periphery of the city.

Results

From the integrative analysis, we identified 4 important ancestral farming technologies that are highly applicable to climate change adaptation—terraces, *waru-waru* (raised beds), and *qochas* and *albarradas* (*jagueyes*) (2 types of reservoir). Because change in rainfall patterns is one of the greatest threats posed to agriculture by climate change, ancient water management techniques such as these are crucial adaptive technological responses. Each of these practices is also associated with the production of key foods in indigenous diets.

Terraces

Terraces have been central to Andean agriculture for >2 millennia (13). In their most basic form, terraces are constructed platforms on mountain slopes, connected by water channels (16). During the 14th and 15th centuries, the Incas improved this ancient technology by incorporating underground aqueducts and complementary irrigation systems (16–18). In Peru, terraces cover an estimated 2 million hectares; however, only 25% are still in use (18). The terraces are built on a soil and clay base that helps to prevent water loss (18), promoting the optimal use of water resources, preventing soil erosion caused by heavy rainfall, and reducing the impact of frost and cold winds (18, 19). Terraces have the potential of increasing food per production unit; according to Altieri (19, p. 3), "first year yield data from new bench terraces showed a 43–65% yield increase in potatoes, maize, and barley compared to yields of these crops grown on sloping fields" (**Figure 2**).

The literature is consistent with our experiences in the field; in the case of the community in the central highlands, informant testimonials affirmed that the terraces are pre-Incan and have maintained a steady rate of food production from past to present by protecting crops and soil from the effects of heavy rains, frost, wind, and hail. In the case of hillside farms in Quito's periphery, the terraces are in a constant process of reconstruction due to urban development, but also represent a convergence of indigenous ecological knowledge with agroecology and permaculture technologies. This combination of ancestral technologies and more modern strategies has produced foods free of agrochemical inputs and pesticides, both for subsistence and for sale in organic farmers' markets for over a decade. In both cases, it is striking how terraces support highly diverse polycultures characterized by ecological interactions, water retention traps through swales and green matter, and notably reduced angles in the slopes.

Waru-waru (*wachos, camellones*): raised fields or raised beds

The *waru-waru* are appropriate in flood-prone areas, such as those in Lake Titicaca shared by Peru and Bolivia (18, 20) and in coastal areas in Ecuador (15). The *waru-waru* represent a technology that helps to balance the level of moisture in the soil for cultivation of tubers and grains, while increasing soil fertility (20). *Waru-waru* are a series of raised beds connected by a network of earth channels that prevent or delay flooding, while maintaining crop yield during periods of drought due to the moisture stored in the soil (18, 15). From a climate change perspective, this technique also reduces the impact of frosts: the water and biomass in the canals absorb the sun's heat during the day and radiate it back at night (20). The raised beds also diminish the effects of El Niño events, which flood most of the lowland areas, allowing traditional crops such as maize and tubers to remain above flood levels (**Figures 3** and **4**).

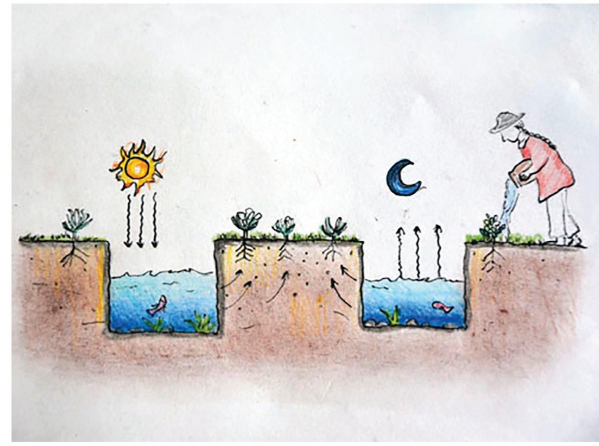

FIGURE 3 Esparta Sevilla. *Waru-waru* (*wachos*, *camellones*): raised fields or raised beds. 2020.

Waru-waru also maximize productivity insofar as the water channels are used to raise aquatic fauna (fish and waterfowl) and cultivate plants adapted to humid or wet environments, such as rice (21). The plants and animals living in the channels not only provide protein, but also act as fertilizer for the polycultures grown on the beds. In addition, this technique results in more nutritious harvests, as well as high yields per unit of land cultivated (20, 22). Although historical processes and migration have significantly reduced the use of raised fields in coastal Ecuador (15), the raised fields remain associated with key crops such as maize, sweet potato, squash and cassava, different varieties of

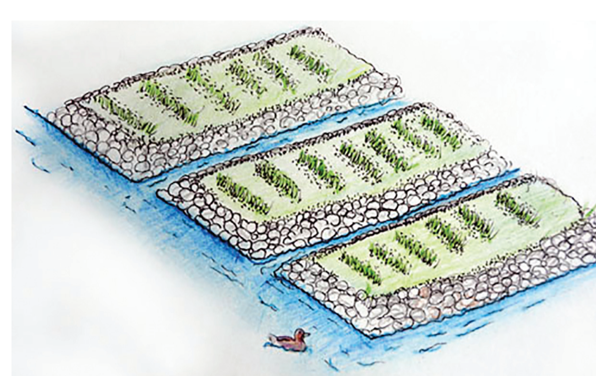

FIGURE 4 Esparta Sevilla. *Waru-waru* (*wachos*, *camellones*): raised fields or raised beds. 2020.

FIGURE 5 Esparta Sevilla. Qocha. 2020.

fish, ducks, and geese, and charapa turtles (*Podocnemis unifilis* and *P. expansa*).

Qochas and *albarradas*

The *qochas* and *albarradas* are similar technologies developed in distinct ecological regions to store water. Both technologies use sloping land to catch water and channel it to a *qocha* or *albarrada* where water accumulates. The *qochas* system of the highlands allows soil management that improves fertility, and the water storage allows Andean highlanders to farm (23). Similarly, *albarradas*, found in middle and lower elevations just below Ecuador's dry forests (15), store water during the rainy season, when there is an excess of water, for use during the dry season. In sum, both *qochas* and *albarradas* act as water storage devices in combination with pasture, crops, and feed for animals (**Figure 5**).

In the context of unpredictable rainfall concurrent with climate change, water retention and management is a critical adaptive farming technique. Although the function is the same, the techniques were developed to operate in specific altitudinal zones and ecosystem contexts, resulting in important distinctions. For example, the *qochas* of the high Andes receive water absorbed from the moisture of the environment through the páramo ecosystem. Water is channeled to the *qochas*, from where it is distributed to the lowland areas. In contrast *albarradas* are located in dry forest, strategically positioned at the base of the slope to retain runoff water (24).

Both water retention systems allow the indigenous community flexible control of rainwater in areas facing severe droughts interspersed with intensive flooding events (15, 23). *Qochas*, in particular, moderate the microclimate in their surroundings, generating more moisture and allowing native vegetation to grow (23). In our ethnographic community research, we observed communities in the central highlands working together to recover and restore *qochas*, an important strategy to promote ecosystem restoration and greater water availability. In addition to water foer crop production, the coastal region's *albarradas* serve as an oasis during the dry season, helping both domestic and wild animals to survive.

Food security with food sovereignty in the Andes

The importance of ancestral technologies such as those discussed above is seen in the wide diversity of nutrient-rich crops the technologies support in these traditional agroecosystems. Andean farms, according to Altieri and Koohafkan (1), grow an average of 34 different crops; in some areas, farmers cultivate as many as 50 varieties of potatoes in their plots, whereas their communities can have ≤100 local varieties. This wide variety and genetic variability is positively adaptive, because it decreases the threat of crop loss due to pathogens and pests (1). Through the literature and field observations, we documented 36 indexed crops that support food sovereignty and are regularly grown using these ancestral technologies. **Table 1** presents the micronutrient content per 100 g of key foods produced using ancestral technologies (25), a critical consideration given that serious nutrient deficiencies affect the indigenous populations (22).

Ancestral farming technologies represent an important link with crops that are culturally accepted but also diversify local communities' diet—critical considerations related to food sovereignty. Concurring with Kulhein (26): "the traditional food systems of indigenous peoples contain a wealth of micronutrients that have been poorly described and reported in scientific literature." Consequently, it is important that the nutritionally rich agrifood systems defined by ancestral technologies are leveraged to address the important micronutrient deficiencies experienced by many indigenous populations (27).

Discussion

Ancestral farming technologies, discussed beyond the perspective of adaptation to and mitigation of climate change and food sovereignty, are essential to halt the expansion of the agrarian frontier by ensuring that essential ecological services continue to act as mitigation mechanisms (19). Furthermore, the FAO's Globally Important Heritage Systems (28) state that, "Andean agriculture is one of the best examples of the adaptation and knowledge of farmers to their environment for more than 5000 years." Andean crops have a high level of resistance to environmental variation (5), but this tandem analysis of the literature and primary research in Ecuador shows that indigenous people are key players in preserving and promoting ancestral farming technologies.

Evidence presented and discussed suggests that these technologies can be important and effective mechanisms for adaptation to climate change, providing micronutrient-dense traditional diets to indigenous communities, at the same time maintaining the symbolic value of these technologies. From a climate change mitigation perspective, these ancestral farming and water management techniques are proven to enhance diversity and reduce soil erosion, and do not rely on pesticides and fertilizers derived from fossil fuels, which are among the main sources of greenhouse gas emissions (29). Combining analysis of agriculture and nutrition in the face of climate change is very important to develop sustainable food systems and ensure food security (30).

Growing interest in these ancient technologies from international and governmental organizations is helping moves toward their incorporation in public climate change policies. For example, in 2007, Bolivia formally incorporated indigenous ecological knowledge in its Na-

TABLE 1 Indexed crops by agricultural technologies and their micronutrient content per 100 g food[1]

English name	Scientific name	Agricultural technique	Micronutrient content, in 100 micrograms (mg)
Oca	*Oxalis tuberosa*	Terraces	Fe 1.84 Ca 2 P 36 Vitamin C 38.4
Amaranth	*Amaranthus*	Terraces	Ca 150 Fe 530 K 800
Lupin beans	*Lupinus albus*	Terraces/*waru-waru*	Ca 1 Fe 0.11 K 302 P 24 Zn 7
Squash	*Cucurbita maxima*	Terraces/*waru-waru*/*albarradas*	Ca 32 P 32 Fe 0.50
Pumpkin	*Cucurbita* sp.	Terraces/*waru-waru*/*albarradas*	Ca 20 P 57 Zn 0.15 Fe 0.60
Quinoa	*Chenopodium quinoa*	Terraces/*qochas*	Ca 56 Fe 242 P 3.30 Zn 5.30
Mortiño or Andean blueberry	*Vaccinium meridionale*	*Qochas*	Ca 26 F 16 Vitamin C 11
Cañihua	*Chenopodium pallidicaule*	*Qochas*	Ca 87 P 335 Fe 10.80
Passion fruit	*Passiflora nitida*	*Waru-waru*	Ca 1 Fe 0.11 K 284 P 34 Zn 0.17
Chili	*Capsicum* sp.	*Waru-waru*/*albarradas*	Ca 31 P 21 Fe 3.50
Cassava	*Manihot esculenta*	*Waru-waru*/*albarradas*	Ca 5 P 59 Fe 0.30
Bocachico fish	*Prochilodus reticulatus magdalenae*	*Waru-waru*/*albarradas*	Ca 45 P 477 Fe 4.80
Tiger catfish	*Pseudoplatystoma fasciatum*	*Waru-waru*	Ca 28 P 258 Fe 0.70
Sweet potato	*Ipomoea batatas*	*Waru-waru*	Ca 6 P 40 Fe 0.50
Ducks	*Anas platyrhynchos*	*Waru-waru*/*albarradas*	Ca 15 P 188 Zn 1.36 Fe 1.80
Geese	*Anser* sp.	*Waru-waru*/*albarradas*	Ca 43 F 261 Zn 3.07 Fe 30.53

[1] Micronutrients are sourced from INFOODS's Latin American food composition tables (25).

tional Climate Change Adaptation Mechanism policy (18). In Peru, indigenous ecological knowledge was used in the formulation of the Second National Communication on Climate Change in 2010, whereas the Ministry of Agriculture itself is building 50 *qochas* in Cusco to address climate change (31). In Ecuador, indigenous ecological knowledge is recognized in the 2008 Constitution, and the Ministry of Environment incorporated ancestral technologies in the Climate Change Adaptation Project (PACC) (32). Ecuador's Water Management Secretariat promoted the construction of *albarradas* in Santa Elena to provide water for cultivation, requiring that *albarradas* be built using ancient technologies because of their greater efficiency.

Regardless of whether *waru-warus* are considered a relic technology, they are in use. Programs for recovering ancestral technologies have proved, both in the lower Guayas Basin in Ecuador and around Lake Titicaca, that *waru-warus* are an important tool for maximizing crop output. Nevertheless, it is important to mention that the efforts to reintroduce this technique in the Titicaca area were not so successful, which helped to create awareness of the importance of putting greater effort into reintroducing this technology to meet desired outcomes (33). Some of the explanations for the unsuccessful reintroduction of the technique expose a disconnection from the ancestral memory. However, it is important to note that some communities were given the opportunity to reuse such technology, which resulted in success in Manabí and Santa Elena in Ecuador (20, 24, 34).

Promotion of Andean ancestral technologies has the potential to provide local communities with tools to adapt to and mitigate climatic change while enhancing food production. The technologies discussed here represent sustainable methods that promote both agrodiversity and the production of nutritious food for often food-insecure populations. In this context, it is relevant to consider the connection between the ancestral farming technique with traditional crops and the nutritional benefits of these crops for the community's health. This topic remains poorly reported in scientific literature, and it is important to recognize that indigenous peoples' traditional knowledge could help to mitigate and adapt to climate change while securing micronutrient-rich diets. Consequently, indigenous people have the capacity to shift from being among the most vulnerable to becoming agents of change, capable of contributing to the climate change challenge while simultaneously contributing to food security and food sovereignty in the region and beyond.

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